IDA

INSTITUTE FOR DEFENSE ANALYSES

Status of DoD's Capability to Estimate the Costs of Weapon Systems

Stephen J. Balut, Project Leader
Vance Gordon
Theresa O'Brien
Richard Bishop
Richard Collins

April 1998

IDA Document D-2149
Log: H 98-001046

This work was conducted under contracts DASW01 94 C 0054/ DASW01 97 C 0056, Task T-Q7-1138, for the Office of the Director, Program Analysis and Evaluation. The publication of this IDA document does not indicate endorsement by the Department of Defense, nor should the contents be construed as reflecting the official position of that Agency.

INSTITUTE FOR DEFENSE ANALYSES

IDA Document D-2149

Status of DoD's Capability to Estimate the Costs of Weapon Systems

Stephen J. Balut, Project Leader
Vance Gordon
Theresa O'Brien
Richard Bishop
Richard Collins

PREFACE

The Institute for Defense Analyses (IDA) prepared this document for the Office of the Director, Program Analysis and Evaluation, under a task entitled "Cost Research Symposium." This document contains an assessment of DoD's capabilities to estimate the costs of weapon systems. The assessment was originally presented by a panel of representatives from the Office of the Secretary of Defense and the Military Departments at the 31st Annual DoD Cost Analysis Symposium conducted on February 3–6, 1998, in Williamsburg, Virginia.

This document is in the form of an annotated briefing, augmented with additional information, including lists of offices who provided data the panelists used to develop scores for DoD's capabilities by commodity type (e.g., aircraft, ships, etc.).

The panelists and their contributions to the presentation are as follows:

- Stephen J. Balut, IDA—introduction and closing;
- Vance Gordon, CAIG—OSD perspective;
- Theresa O'Brien, AFCAA—space systems, fixed-wing aircraft, and rotary-wing aircraft;
- Richard Bishop, USACEAC—missiles and surface vehicle systems; and
- Richard Collins, NCAA—electronics and ships.

Because it contains no original analysis, this document did not undergo internal IDA review.

CONTENTS

I. INTRODUCTION

Stephen J. Balut, Institute for Defense Analyses

Status of DoD's Capability
to
Estimate the Costs
of
Weapon Systems

A Panel Discussion

Good morning. Welcome to the Cost Research Session.

As you know, the purpose of cost research is to develop and improve the data and methods we use to conduct cost analyses.

Here's what I'm going to do before I turn the floor over to our panel. First, we're going to have a short quiz. Then I will tell a short story that illustrates why we do cost research. Then I'll describe the DoD Cost Research planning cycle. Finally, I will introduce the panel discussion by telling you what will be assessed, the question being answered, the dimensions of the question, the scoring method, what our prior expectations were, and lastly, I will introduce each member of the panel.

I know many of you attended our earlier sessions on cost research. I want to find out how well you were listening. We're going to have a quiz—a short one—one question. Let's see who gets the right answer.

Last year, I told you about my trip to West Africa to see my son who was serving in the Peace Corps. He taught me, and I told you, the Bambara word for "estimate," along with its literal translation. I doubt anyone would remember the Bambara word—its "jatimine (jaw-tee-mee-nay)." But someone might remember the literal translation. The quiz question is—what is the literal translation of "jatimine?" Anyone? Shout out the answer. [Response from the audience—"Grab a number."]

Unlike the story last year, this one is completely fictitious. I use it only to make a point. Here's the hypothetical situation.

Someone walks into your office and asks you, "How much will the JSF cost?"—and the answer is wanted right away. The answer you give will depend on the information available to you at that moment. This set of information, whatever it is, might include data on the JSF, similar data on analogous systems, and cost estimating methods that relate the tactical aircraft program characteristics to costs.

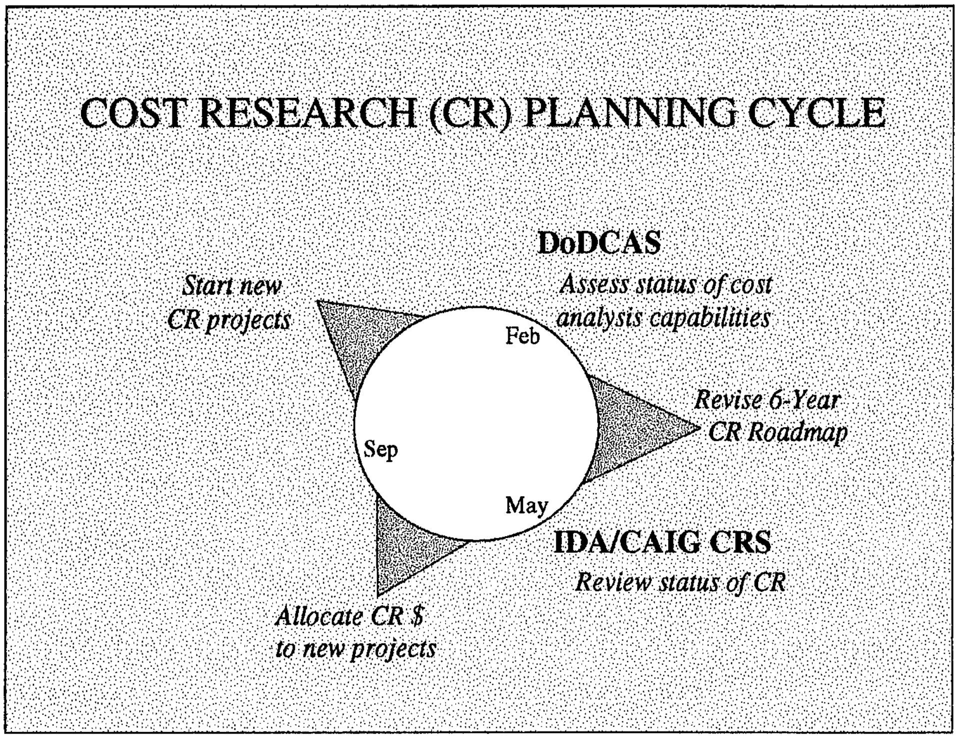
If at the moment, you have little or no information related to the JSF, you could "grab a number." That is, *not* having data and methods will not stop you from offering up a number. You might say, "About $35 million per copy, but I have no hard evidence to back up that number." In this case, the credibility of your grabbed number estimate is about zero. It will be of little or no use to the requestor.

Let's suppose a different situation. Suppose you do have information. You go to your safe, pull out data on the JSF (i.e., physical, technical, performance, programmatic, and cost) and also on analogous systems. Then you go to your bookshelf and select the preferred method for estimating the costs of tactical aircraft. You develop an estimate using these tools and also use statistical methods to determine the extent of error in your estimate (as determined by the data and methods you used). You deliver your new estimate to the requestor. Let's say it's $30 million per copy, and you provide a confidence band around this point estimate and identify the sources of uncertainty. You show the requestor the data you used and the methods you applied. *Now* your estimate is useful and has some degree of credibility.

In these scenarios, your capability to estimate the desired costs was determined, in large part, by the data in your safe and the methods on your bookshelf. These data and methods were the results of prior investments in cost research.

This story illustrates that the current level of our capabilities to do cost analyses and estimate the costs of weapon systems is no accident. They have been determined, in large part, by prior investments. Likewise, our future capabilities will be determined by the investments we make today and tomorrow.

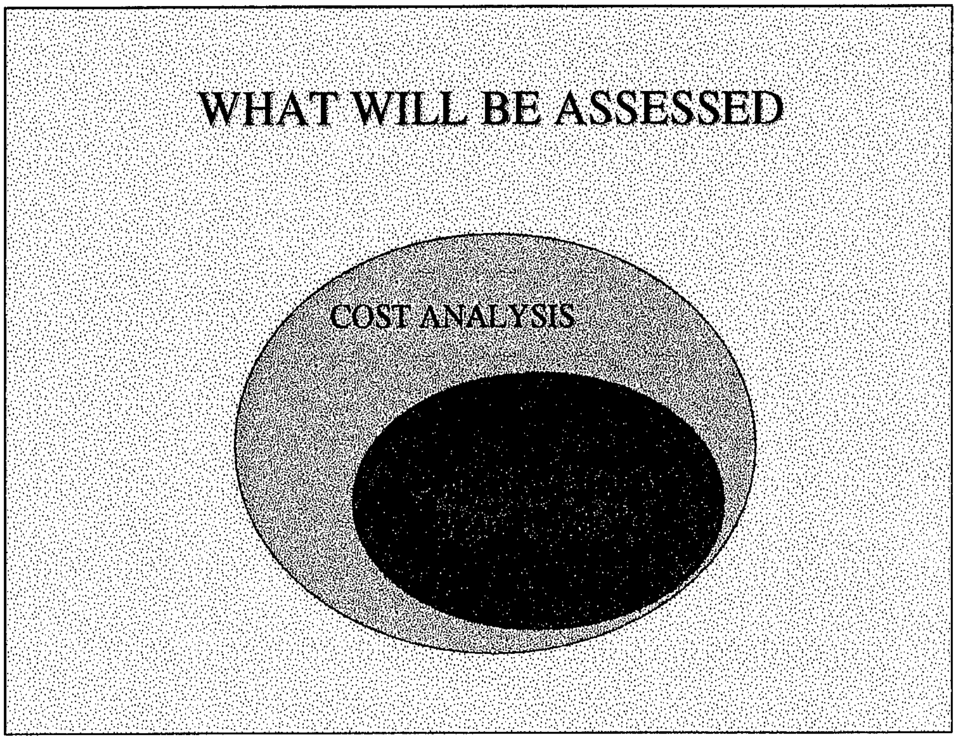
Cost research dollars are very scarce and must be carefully planned. Our investment decisions must be informed in several ways. We need an understanding of our current capabilities; we need a view of where our needs for improvement are greatest in light of pending challenges; and, just as important, these decisions, which we make in a decentralized way, need to be informed with visibility into where *other* research sponsors are making their investments.



This slide shows the cost research planning cycle that has evolved in the DoD. The process imposes some order and even efficiency on the process by which sponsors choose to invest their scarce cost research dollars. The two main events in this cycle are the DoDCAS and the IDA/CAIG Cost Research Symposium. You are familiar with DoDCAS. You're here. At this meeting we learn the status of DoD's cost analysis capabilities—through meetings, training sessions and panel discussions.

Some of you may not be familiar with the IDA/CAIG Cost Research Symposium. It was initiated to answer the question, "What cost research is going on today—and, to the extent it's known, what is planned for tomorrow?" This symposium started nine years ago. I was sitting at my desk, thinking about what I was going to spend my independent research dollars on. I realized I knew nothing at all about what other offices (military departments, OSD, other FFRDCs, universities) were doing now or what they were planning to do. I picked up my phone and invited my colleagues to come to IDA and exchange information. We did that. Our meeting resulted in more informed decisions on what investments to make. In addition, we exchanged data and findings and even decided to jointly fund certain research projects of common interest. We've been meeting this way ever since. The CAIG started co-sponsoring this meeting in 1993.

So, [*referring to the slide*] the planning cycle starts with an assessment of cost analysis capabilities—here at DoDCAS. This results in identification of areas where *more* research is needed. You'll see these areas in a few minutes. The Six-Year Cost Research Plan is updated during the spring, based on what we know as of the time of DoDCAS. Then, all *ongoing* cost research activities are reviewed and cataloged at the IDA/CAIG Cost Research Symposium. At about this time, sponsors with cost research money are ready to make their investment decisions for the next fiscal year. At this point, they know the status of existing capabilities, to include areas where more research is needed, and they have visibility into ongoing research. The allocations of funds to new research projects are made in the summer, and new research projects start up with the beginning of the new fiscal year.



Our panel is going to present to you their assessment of capabilities as of right now. This assessment reflects the data we, the entire defense cost community, have in our safes and the methods we have on our bookshelves right now.

This assessment will not address all areas of cost analysis. We decided we simply did not have enough time to do all of that in an hour. Our assessment will be limited to the DoD's capability to estimate the costs of weapon systems. Assessments were derived by first talking to the people in the DoD who actually do these estimates—and then aggregating their individual subjective judgments.

Now, let's be clear on what is *not* included in today's assessments. They do not explicitly include the effects of the so-called revolution in business affairs, the effects of acquisition reform, of acquisition streamlining, of IPTs and the like. These effects are being studied now and have yet to be incorporated into our cost estimating toolbox.

Also, our focus on weapon systems excludes automated information systems, force costing, and infrastructure costing.

SCENARIO

- Situation:
  - You are responsible for estimating the cost of a weapon system in preparation for a major milestone review.
- Question:
  - How well are you prepared to do this today?

This slide shows the question that was put to cost analysts in DoD offices that are responsible for estimating the costs of weapon systems. It asks for a subjective assessment of capability to estimate the costs of a specific weapon system at the time of a specific milestone decision. For example, "How good is your capability to estimate the cost of a tactical aircraft at the time of an EMD (milestone II) decision?" Or, "How good is your capability later, at the time of the production milestone decision?" One would expect capability to be better at the production milestone because more data would be available—to include costs experienced during EMD and LRIP.

DIMENSIONS

- Systems
  - Space Systems
  - Aircraft
  - Electronics
  - Ships
  - Missiles
  - Surface Vehicle Systems
- Milestones
  - PDRR
  - EMD
  - Production
  - O&S

Assessments will be provided for all major commodities included in Military Standard 881B, except ordnance. We prepared an assessment of ordnance, but the number of people who submitted their judgments was small, and the results raised questions. We will try to do a better job on ordnance next time.

Assessments will be provided for the three major milestones and also for O&S. The question put to the experts about O&S costs was not related to any specific milestone, but rather just a general assessment.

SCORING

- ***GREEN*** - Capabilities good or better
  - Adequate data available
  - CERs/Models available and up-to-date
  - Expect small to moderate error in estimates
- ***YELLOW*** - Capabilities marginal
  - Some data available - additional data needed
  - CERs/Models available but not current
  - Expect moderate to large errors in estimates
- ***RED*** - Capabilities poor
  - Data lacking
  - CERs/Models not available or of little use
  - Expect large to unknown errors in estimates

Here is the color coding used by the experts to score their assessments. Green means capabilities are believed to be good or better. This means adequate data are available now, CERs/models are available now, and we feel that the error in estimates will likely be small to moderate.

Yellow indicates a feeling that capabilities are marginal. This means we don't have all the data we need, CERs are around but may not be current or directly applicable, and we might have moderate to large errors in our estimates.

Red says our capabilities are poor. Data are lacking, CERs/models are of little use, and we suspect our estimates may contain errors that are large or worse.

We allowed (and our responders submitted) assessments that included in-between points. So, you will see assessments such as red-yellow and yellow-green. These mean capabilities are judged to be not as bad as the left (or first) color, but not as good as the right (or second) color.

PDRR Characteristics

- Little definition of program being estimated
- Paucity of historical cost data
  - Limited hardware/software of varying configurations (e.g., breadboard, brassboard, etc.)
  - Nonrecurring vs recurring hardware cost visibility often unavailable
  - Moderate-to-significant internal contractor cost contribution not reflected in the data
- Limited analogies & few-or-no *meaningful* estimating relationships

Capabilities poor to marginal

The next four slides identify, by phase, the scores we expected and the reasons why.

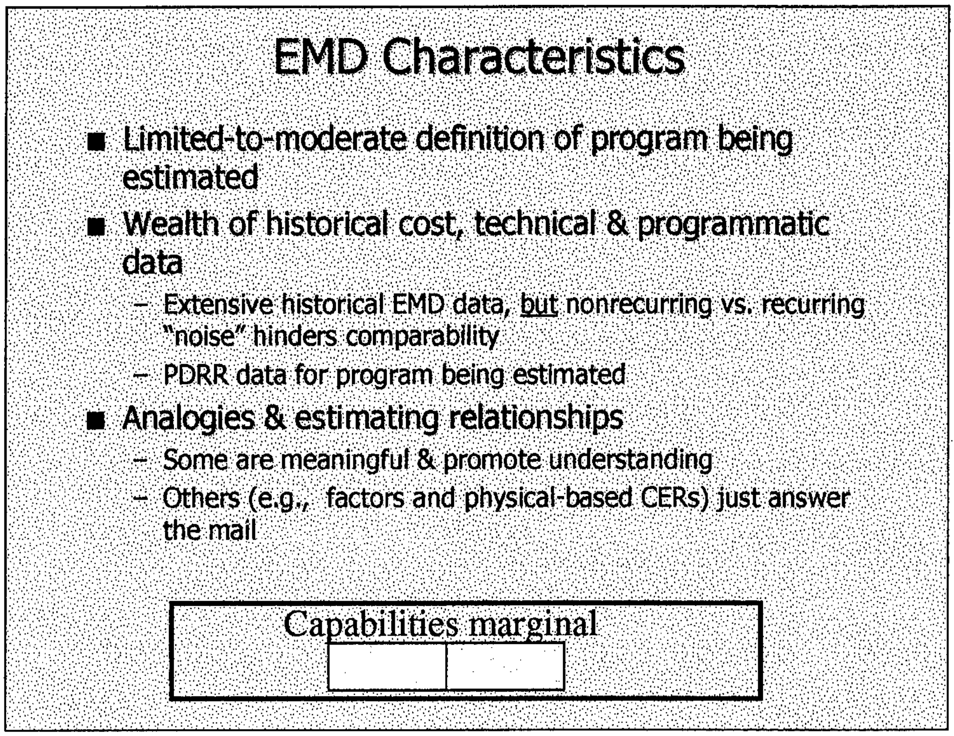
At Milestone I, the decision to enter the PDRR phase (previously known as Demonstration and Validation), we expected a red-yellow score for DoD's PDRR cost estimating capability.

First, the program being estimated tends to be ill defined with respect to the technical baseline.

Second, historical weapon systems databases suffer from a severe lack of PDRR data. Several factors contribute to this void. There is generally a limited amount of deliverable hardware and software developed during this phase, and often the hardware built is not a full-up system. This is practically always the case for electronics, whose PDRR phase typically involves development of breadboard and brassboard hardware for potentially risky subsystems and components. Another factor that contributes to the PDRR data void is the quality of deliverable (i.e., to the government) cost data. The most common problem is lack of detail, which results in inability to distinguish between nonrecurring and recurring hardware (i.e., design vs. build) costs. The final factor contributing to the PDRR data void is that contractor costs reported to the government do not include what is quite often moderate to significant internal contractor investment in the PDRR effort. To explain, typical program acquisition strategies include PDRR contract awards to at least two competing contractors or contractor teams and subsequent competition for a single EMD

award. The desire to get the competitive edge in preparation for the downselect is a strong incentive for a PDRR contractor to expend internal funds. Understandable though unfortunate for cost analysts, there is no requirement for the contractor to disclose these internally funded costs. The absence of these costs from our historical databases has a negative impact on our ability to truly understand PDRR costs and, perhaps more importantly, their relationship to EMD phase costs.

Third, as a result of the quantity and quality of PDRR data, there exist some macro cost estimating analogies and factors, but few or no meaningful relationships that explain PDRR costs.



At Milestone II, the decision to enter the EMD phase, we expected a yellow score for DoD's EMD cost estimating capability.

First, the program being estimated tends to be better defined now (vice at Milestone I) with respect to the technical baseline. In fact, program definition can be generally characterized as limited to moderate.

Second, historical weapon systems databases include a wealth of EMD cost data and associated technical (i.e., physical and performance) and programmatic data from which EMD cost estimating methodology can be developed. Some of the cost data (in particular, CCDR data) provide visibility into nonrecurring vice recurring hardware costs. This detail enables an analyst to distinguish prototype design costs from prototype build costs, a distinction that is paramount to meaningful EMD cost estimating methodologies. However, other deliverable cost data (i.e., CPR and C/SSR data) typically do not provide similar visibility. In addition to having access to a wealth of EMD cost data, an analyst preparing an estimate in support of Milestone II will have access to PDRR actuals for the program being estimated. The previous slide highlighted the limitations associated with PDRR data, but the data can be useful, if for no other reason, as a sanity check of specific costs. For example, the systems engineering costs reported for PDRR can be used to compute an actual cost per month PDRR burn rate, which can be compared to the estimated EMD burn rate derived from historical EMD data.

Third, due largely to the fact that significant EMD data exists, there are a variety of existing and potential cost estimating methodologies available to cost analysts at Milestone II. Some of these methodologies, which include analogies, factors, and statistical parametric relationships, are meaningful with respect to explaining costs. Others are not and just "answer the mail" (i.e., produce an estimate).

Production Characteristics

- Good definition of program being estimated
- Wealth of historical cost, technical & programmatic data
  - Extensive historical production data; less nonrecurring vs recurring "noise" enables better comparability
  - EMD data for program being estimated
- Extrapolation, analogies & estimating relationships
  - Cost vs. learning & rate relationships well established
  - Better relationships between HW cost & performance

Capabilities marginal to good

At Milestone III, the decision to enter the Production phase, we expected a yellow-green score for DoD's production cost estimating capability.

First, the program being estimated tends to be well defined. The EMD Phase is completed or nearing completion and, as such, the technical baseline is maturing.

Second, historical weapon systems databases include a wealth of production cost data and associated technical (i.e., physical and performance) and programmatic data from which production cost estimating methodologies can be developed. Since production effort is primarily recurring in nature, the EMD estimating challenge posed by the nonrecurring versus recurring distinction is little to no problem for production estimating. (Note: an exception is special tooling and test equipment cost, which does have an important nonrecurring component.) This provides analysts some degree of confidence that the data for different programs are comparably defined. Finally, in addition to having access to a wealth of production cost data, an analyst preparing an estimate in support of Milestone III will have access to EMD actuals for the program being estimated. Depending on its granularity, this EMD data can be an invaluable resource for estimating first unit recurring production hardware costs.

Third, due largely to the fact that significant EMD and production data exists, there are a variety of existing and potential cost estimating methodologies available to cost analysts at Milestone III. Furthermore, the reduced (i.e., relative to EMD) uncertainty in production cost data alluded to above translates into reduced uncertainty in the cost estimating methodology derived from the data and therefore more meaningful methodology.

O&S Characteristics

- Wealth of historical cost & programmatic data via Services' VAMOSC systems, *but*
  - some important cost elements are missing or incomplete
  - level of cost data detail not always adequate
- Analogies & estimating relationships that answer the mail, but do not facilitate understanding
  - Relationships between cost & reliability, maintainability & availability parameters are understood, but not quantified
  - Relationships between cost and system technical parameters are not understood, no less quantified
  - Limited understanding of O&S activities, and their inter-relationships and cost characteristics

Capabilities marginal

At Milestone III, the decision to enter the Production phase, we expected a yellow score for DoD's O&S cost estimating capability.

First, the Service's respective VAMOSC databases include a wealth of historical cost data for active and retired weapon systems. These databases have formed the principal basis of Service and OSD CAIG O&S cost estimates for weapon systems. Each database has a well-defined cost element structure that facilitates consistency and comparability across weapon systems. However, the VAMOSC databases are not without problems. Some O&S cost elements (e.g., software maintenance and engineering/technical services) are missing or incomplete. Also, in some instances, the data do not provide the visibility required to perform a specific estimate, e.g., at the subsystem or component level.

Second, despite the wealth of historical data, there is a paucity of O&S estimating methodology that supports anything beyond relatively macro cost estimates that just "answer the mail" (i.e., meet Service and OSD requirements to estimate life cycle cost). Methodologies that represent the historical relationship between the cost (e.g., unscheduled maintenance) of a given system and the system's demonstrated reliability, maintainability and availability (RMA) parameters are lacking. Similarly, methodology that represent the historical relationship between a given O&S cost element and a system's performance characteristics (speed, range, etc.) are lacking. Both are essential

to DoD's ability to perform analyses that support the CAIV process for both future and in-service weapon systems. Without these types of methodologies, it is difficult (if not impossible) to conduct the cost-performance trade-offs inherent in the CAIV process. Finally, there is a basic lack of understanding of O&S processes, their interrelationships and their cost characteristics. This final void is beginning to be addressed in cost modeling efforts that employ system dynamics.

PANEL

- Ms. Theresa O'Brien, AFCAA
  - Space Systems
  - Aircraft
- Mr. Rick Collins, NCCA
  - Electronics
  - Ships
- Mr. Richard Bishop, CEAC
  - Missiles
  - Surface Vehicle Systems
- Dr. Vance Gordon, OSD CAIG
  - Consolidation/CAIG Perspective
  - Upcoming DAB Schedule

With that I'd like to introduce our panel and get on with the assessment.

Our first panel member is Ms. Theresa O'Brien. Theresa is the Research Division Chief at the Air Force Cost Analysis Agency. She is responsible for all the Agency's cost research activities and cost support contracts. Prior to joining the Agency, she worked at the Naval Air Systems Command on the F/A-18 program. Theresa earned a master's degree in business administration from Virginia Tech. She will present assessments for aircraft, both fixed wing and rotary wing, and also space systems.

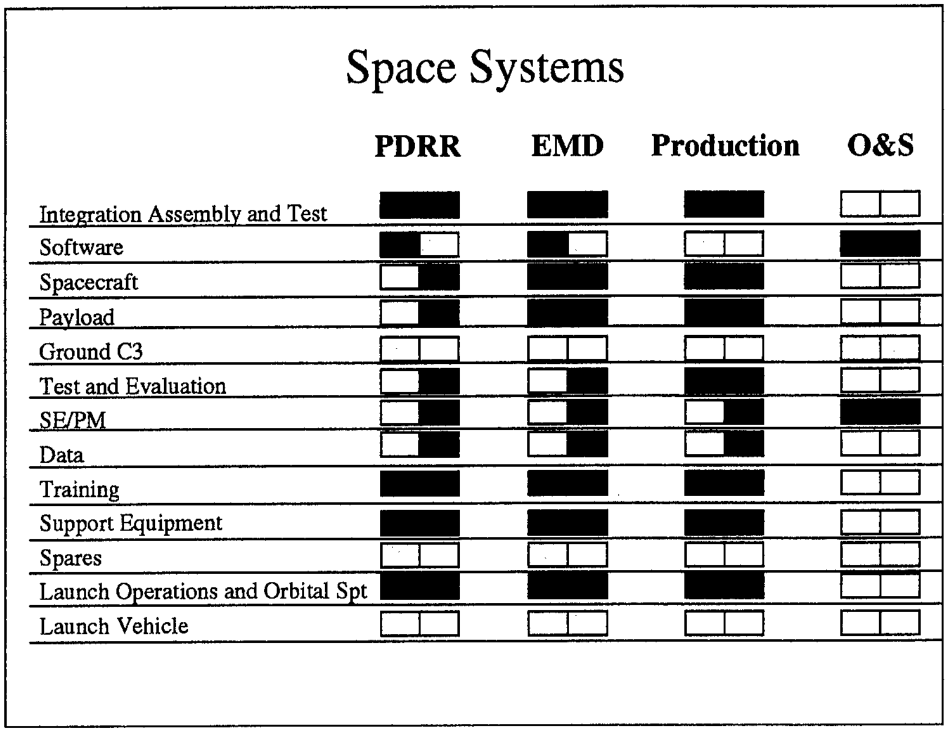
Our next panelist is Mr. Rick Collins. Rick is the Technical Director of NCCA. He coordinates Navy cost research. Prior to his role as Technical Director, he was head of the Ships and Ship Systems Division of NCCA. Prior to joining NCCA, Rick worked as a cost analyst at SAIC. Rick has a master's degree in economics from Virginia Tech and a bachelor's degree in economics from Wake Forest. He will provide assessments for ships and electronics.

Our next panel member is Mr. Dick Bishop. Dick is the Chief of Cost Research at the Army Cost and Economic Analysis Center. He analyzes Army-wide cost research requirements and develops and manages the Army's long-range cost research program. Dick began his government career as an Army Signal Corps Officer. He later worked for IBM as a computer designer. Dick holds a BS degree in electronics engineering and an MS in industrial engineering, both from Oklahoma State University. Dick will present assessments for missiles and surface vehicle systems.

Our last panelist is Dr. Vance Gordon. Vance is a member of the Operations Analysis and Procurement Planning Division of PA&E's Resource Analysis Directorate. Since joining this office, Vance has been responsible for development of DoD cost research guidance. He served previously in PA&E's Projection Forces Division. Dr. Gordon is a graduate of the University of Colorado and received his Ph.D. in population biology from Washington University in St. Louis. He will provide a consolidated perspective on DoD's capabilities and identify some future challenges.

II. SPACE SYSTEMS

Theresa O'Brien, Air Force Cost Analysis Agency



The efforts my colleagues and I have undertaken bring a new twist to the way we view our research capability.

First, it is important to present our current capabilities in space. As you can see, the WBS is down the left and the acquisition phase is across the top. We are viewing our capability at each milestone. In the time allocated, we can not discuss every block, but only highlight the findings. To support the color scheme, we have also documented a list of studies that are commonly used. This list of studies is not to be considered inclusive of all tools. It only represents, in no particular order, the studies provided by the respondents.

Space has several large databases that comprise historical data, Unmanned Spacecraft Cost Model (USCM) and the NASA/Air Force Cost Model (NAFCOM). These databases provide analysts with valuable information; thus, the green coding for items such as Integration Assembly Test, Spacecraft, Payload, Training, and Support Equipment.

Software, as you will see, is mostly red for all commodities. Rick Collins will address software in more detail in the Electronics portion.

Spacecraft as noted above relies on the historical databases. But trends such as the common bus becoming commercialized causes estimating challenges.

Payload has several supporting studies for use in cost estimating. The Air Force is comfortable estimating sensor, communication, and navigation payloads, but when faced with new technology such as cross-links payloads, the Air Force relies on engineering adjustment factors.

Ground C3 systems are causing estimating challenges in the area of COTS Integration.

SE/PM and Data are coded similarly based on the databases of historical data not capturing acquisition streamlining initiatives the contractors are implementing.

Spares estimates are typically not estimated by the weapon system analysts. It is considered a pass-through estimate from other organizations. No clear methodologies or studies were provided.

The Launch Vehicle Cost Model is a valuable resource for estimating EELV. This procurement method for the future, using price negotiation for launch services on the EELV until the year 2020, does not provide insight into the cost of a launch vehicle. The government is acting as a corporation and purchasing the service only. If a future decision were to purchase government owned launchers, there will be no historical data to base our estimates.

Some areas of O&S are clear. This is because of the unique nature of space systems. When a satellite is launched the traditional O&S for the spacecraft are not relevant. Maintenance is done through software uploads by the ground station.

Integration A&T

USCM, Unmanned Spacecraft Cost Model, Tecolote, 1997, (N / R)
NAFCOM, NASA/AF Cost Model, SAIC, 1997, (N / R)
NAVSTAR GPS Data, SMC/FMC, (N / R, 1 program)
GPALs CERs, TASC-Arlington, Jan 93, (N / R multi-programs)
SEER H, Systems Evaluation & Estimation Resources-HW, Galorath Associates, 1997
Space Payload Integration Model, Tecolote, 1994

Software

PRICE S, Martin Marietta, 1997
SEER SEM, Systems Eval & Est Resources-S/W est model, Galorath, 1997
CERs for Space-Based Sys, Defense Communications Agency-DC, Apr 91, (N / R, comm. sys)
Kantors Factors, Cost Factors and Est Relationships, Electronic Sys, Apr 90(S/W productivity)
Saset Software Architecture Sizing & Estimating Tool, Martin-Marietta, Apr 93
Revic, REVised Intermediate COCOMO, AFCAA, Feb 91
SMC Software Sizing Dbase, SMC, 1997

Spacecraft

USCM, Unmanned Spacecraft Cost Model, Tecolote, 1997, (N / R)
NAFCOM, NASA/AF Cost Model, SAIC, 1997 (N / R)
Revised Small Satellites, Tecolote, Nov 91, (N / T1)
CERs for Space-Based Sys, Defense Communications Agency-DC, Apr 91, (N / R, comm.. sys)
S/C Functional CER, IDA for BMDO, Sep 93, (N / R)
NAVSTAR GPS Data, SMC/FMC, (N / R, 1 program)
EPS ECR, Electrical Power Subsystem, Booz Allen, Jun 91, (N / T1)
GPALs CERs, TASC-Arlington, Jan 93, (N / R multi-programs)
High Reliability Parts, MCR, Sept 90, (N/R/O&S)
Elect Power Sys for SDIO Elements, Booz Allen, Jun 91, (Streamlining)
Large Space Power Systems, Aerospace Corp, Aug 88, (N / R, EPS)
CERs for Prop & Reaction Cntrl, Applied Research, Feb 90, (R)
SEER H, Systems Evaluation & Estimation Resources-HW, Galorath Associates, 1997
PRICE H, GE, 1997
Small Satellite Subsys Cost Model, Aerospace, 96, (N/R)
JPL Project Cost Model, Jet Propulsion Lab, (N/R)
TRANSCOST, TransCost Systems, 95 (N/R)
Digital Sig & Data Processor, DSDPM, Tecolote Research, Sept 91, (N/R)
Phase I Acquisition Reform, TASC 1996

Payload

USCM , Tecolote, 1997 (N / R)
Price H / M, Martin Marietta, 1997
SEER H, Galorath, 1997
Passive Space Sensor Model, MCR, May 92, (N / R)
CERs for Space-Based Sys, Defense Communications Agency-DC, Apr 91, (N / R, comm. sys)
Strategic and Exp IR Sensors, Technomics, Mar 93, (R)
Focal Plane Array Cost Est Model, Tecolote, Jul 90, (N / R)
CER for R&D Missile Comm, Applied Research, Mar 90
Kantors Factors, Cost Factors and Est Relationships, Electronic Sys, Apr 90 (S/W productivity)
Scientific Inst Cost Model-SICM, Planning Research, 91 (N/R)
Digital Sig & Data Processor, DSDPM, Tecolote, Sept 91, (N/R)
Non-Rec parts(costs) for Space Sensors, Aerospace for SMC, Oct 91, (N)
Adv Space Processor Model, Tecolote, Sept 89, (N/R)
Dev Eng & BTL Dev Models, Technomics, Aug 90, (N)
Tactical IR Sensor Model, Technomics, Feb 91, (R small payloads)
CER Rationale for Brillant Eyes, Technomics, Apr 91, (N/R)
High Reliability Parts, MCR, Sept 90, (N/R/O&S)
Multi-var Instrument Cost Model, MICM, 90 (N)

Ground C3

Construction Cost Est Handbook, Applied Research, Jun 88, (N / R)
GPALs CERs, TASC-Arlington, Jan 93, (N / R multi-programs)
Fiber Optics Network Study, General Research Corp, Oct 89
JPL Project Cost Model, Jet Propulsion Lab, (N/R)
Ground Ops Cost Model-GOCM, SAIC, 96 (N/R)
Space Ops Cost Model-SOCM, SAIC, (N/R)
TRANSCOST, TransCost Systems, 95 (N/R)

Test and Evaluation

USCM , Tecolote, 1997 (N / R)
NAFCOM, NASA/AF Cost Model, SAIC, 1997, (N / R)
NAVSTAR GPS Data, SMC/FMC, (N / R, 1 program)
Kantors Factors, Cost Factors and Est Relationships, Electronic Sys, Apr 90, (S/W productivity)
GPALs CERs, TASC-Arlington, Jan 93, (N / R multi-programs)
Space & Strat Def Updated CERs, MCR, Dec 87, (N/R, similar to Passive Space Sensor Model)
CER rationale for Brilliant Eyes, Technomics, Apr 91, (N/R, summary of other methods)
Dev Eng & BTL Dev Models, Technomics, Aug 90, (N)

SE/PM

USCM, Unmanned Spacecraft Cost Model, Tecolote 1997, (N / R)
NAFCOM, NASA/AF Cost Model, SAIC, 1997 (N / R)
NAVSTAR GPS Data, SMC/FMC, not known, (N / R, 1 program)
Focal Plane Array Cost Est Model, Tecolote, Jul 90, (N / R)
Kantors Factors, Cost Factors and Est Relationships, Electronic Sys, Apr 90, (S/W productivity)
GPALs CERs, TASC-Arlington, Jan 93, (N / R multi-programs)
Tactical IR Sensor Model, Technomics, Feb 91, (R small payloads)
CER Rationale for Brillant Eyes, Technomics, Apr 91, (N/R, summary of other methods)

Data

USCM, Unmanned Spacecraft Cost Model, Tecolote 1997, (N / R)
NAFCOM, NASA/AF Cost Model, SAIC, 1997 (N / R)
NAVSTAR GPS Data, SMC/FMC, not known, (N / R, 1 program)
Focal Plane Array Cost Est Model, Tecolote, Jul 90, (N / R)
Kantors Factors, Cost Factors and Est Relationships, Electronic Sys, Apr 90, (S/W productivity)
GPALs CERs, TASC-Arlington, Jan 93, (N / R multi-programs)
CER Rationale for Brilliant Eyes, Technomics, Apr 91, (N/R, summary of other methods)
Dev Eng and BTL Dev Models, Technomics, Aug 90, (N/R)

Training

USCM, Unmanned Spacecraft Cost Model, Tecolote 1997, (N / R)
NAFCOM, NASA/AF Cost Model, SAIC, 1997 (N / R)
NAVSTAR GPS Data, SMC/FMC, not known, (N / R, 1 program)
Focal Plane Array Cost Est Model, Tecolote, Jul 90, (N / R)
Kantors Factors, Cost Factors and Est Relationships, Electronic Sys, Apr 90, (S/W productivity)
GPALs CERs, TASC-Arlington, Jan 93, (N / R multi-programs)
CER rationale for Brilliant Eyes, Technomics, Apr 91, (N/R, summary of other methods)
Dev Eng & BTL Dev Models, Technomics, Aug 90, (N)

Support Equipment

USCM, Unmanned Spacecraft Cost Model, Tecolote 1997, (N / R)
NAFCOM, NASA/AF Cost Model, SAIC, 1997 (N / R)
Price H, Martin Marietta, 1997
Seer H, Systems Evaluation & Estimation Resources-H/W, Galorath, 1997
NAVSTAR GPS Data, SMC/FMC, not known, (N / R, 1 program)
Focal Plane Array Cost Est Model, Tecolote, Jul 90, (N / R)
Kantors Factors, Cost Factors and Est Relationships, Electronic Sys, Apr 90, (S/W productivity)
GPALs CERs, TASC-Arlington, Jan 93, (N / R multi-programs)
CER rationale for Brilliant Eyes, Technomics, Apr 91, (N/R, summary of other methods)
Dev Eng & BTL Dev Models, Technomics, Aug 90, (N)
Space and Strat Def Updated CER, MCR, Dec 87, (N/R, similar to Passive Space Sensor Model)

Spares

Kantors Factors, Cost Factors and Est Relationships, Electronic Sys, Apr 90, (S/W productivity)
GPALs CERs, TASC-Arlington, Jan 93, (N / R multi-programs)

Launch Operations & Orbital Spt

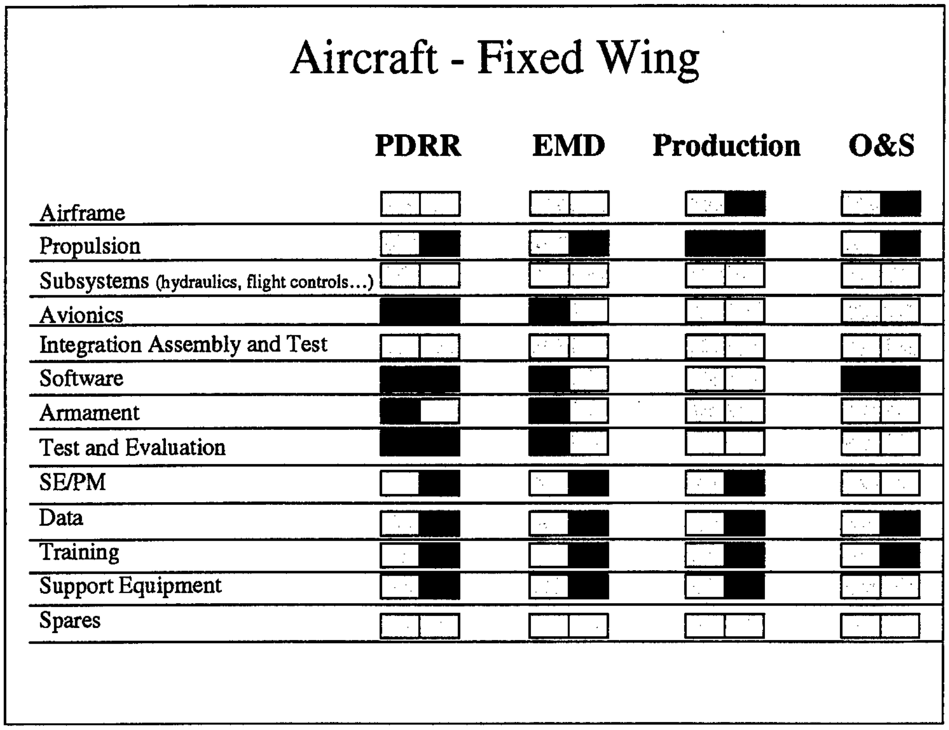
USCM, Unmanned Spacecraft Cost Model, Tecolote, 1997, (N / R)
Construction Cost Est Handbook, Applied Research, Jun 88, (N / R)
Space and Strat Def Updated CER, MCR, Dec 87 (N/R, similar to Passive Space Sensor Model)
TRANSCOST, TransCost Systems, 95 (N/R)

Launch Vehicle

Launch Vehcile Cost Model, Tecolote, 95, (N / T1)
NAFCOM, NASA/AF Cost Model, SAIC, 1997 (N / R)
Liquid Rocket Engine Cost Model, Rockwell, 96, (N/R)
TRANSCOST, TransCost Systems, 95 (N/R)
Digital Sig & Data Processor, DSDPM, Tecolote Research, Sept 91, (N/R)

III. FIXED-WING AIRCRAFT

Theresa O'Brien, Air Force Cost Analysis Agency



Fixed-Wing Aircraft is the next commodity to be discussed.

An abundance of historical airframe databases is available to the cost analyst. The challenges for an estimator with new systems revolve around the material complexity, stealth, and raw material/purchased parts. Material type, such as estimating composites, is a current difficulty on systems such as the JSF. This is primarily due to large composite systems not yet under production. Cost-estimating relationships are currently being derived to assist in this area. The improvement in production to a yellow/green is because one can rely on LRIP units.

The propulsion area has a current, detailed database available to analyst. The challenge is capturing the cost to enhance existing systems.

Subsystems are assigned yellow due to current efforts to do more with less space and using integrated systems versus federated systems.

For Avionics, new integrated systems must rely only on F-22 EMD actuals. The studies listed on the following slides are out-dated. This is an important area for focusing future research efforts.

Software estimating is troublesome. Tools to estimate software are available, but the inputs into these tools have not been collected for historical programs.

For armament, analogies are used but there is no study or database containing these analogies.

SE/PM, Data, Training, and Support Equipment are coded similarly based on the databases containing the historical data not capturing acquisition streamlining initiatives the contractors are implementing.

Aircraft modification challenges are embedded in the coloring scheme. The challenges in structural and avionics modifications present areas requiring further research.

In O&S, one survey noted that part obsolescence has become a difficult issue for the estimator.

Survey respondents for fixed-wing aircraft include AFCAA, ASC, NCCA, and NAVAIR.

Integration Assembly & Test	
	MACDAR Fighter Aircraft Database, Tecolote, 1997
	Cost Factors for A/C and Missiles, Aeronautical Systems Division, May 87
	C3 Platform Integration Cost Model, MCR, 1997
	Kanter's Factors, Cost Factors and Estimating Relationships, Electronic Sys Division, Apr 90
	Aircraft Avionics & Missile System Installation Cost Study, MCR, 1988
	A Parametric A/C Avionics and Missile System Installation Cost Model, MCR, 1986
	Price H
	Standard Cost Factors Handbook, NCCA, 1992
Airframe	
	MACDAR Fighter Aircraft Database, Tecolote, 1997
	Advanced Fighter Aircraft Cost Model, AFCAA, 1997
	Composites/Exotic Materials Database, Tecolote, 1997 (N/R)
	Advanced Airframe Structural Materials, RAND Study, 1991
	Aircraft Airframe CERs, RAND, 87 (Total Level)
	Military Tactical Aircraft Development Costs, IDA, 1988
Propulsion	
	MACDAR Fighter Aircraft Database, Tecolote, 1997
	NAVAIR/AFCAA Engine Study, Ketron, 1997 (N/R)
	Advanced Fighter Aircraft Cost Model, AFCAA, 1997
	GFE, NAVAIR Database, 1997
	Development and Prod. Cost for Military Aircraft Turbine Engines, IDA, 1992
	Military Tactical Aircraft Development Costs, IDA, 1988
SubSystems	
	MACDAR Fighter Aircraft Database, Tecolote, 1997
	Advanced Fighter Aircraft Cost Model, AFCAA, 1997
	GFE, NAVAIR Database, 1997
	Military Tactical Aircraft Development Costs, IDA, 1988
	PRICE H
	SEER H

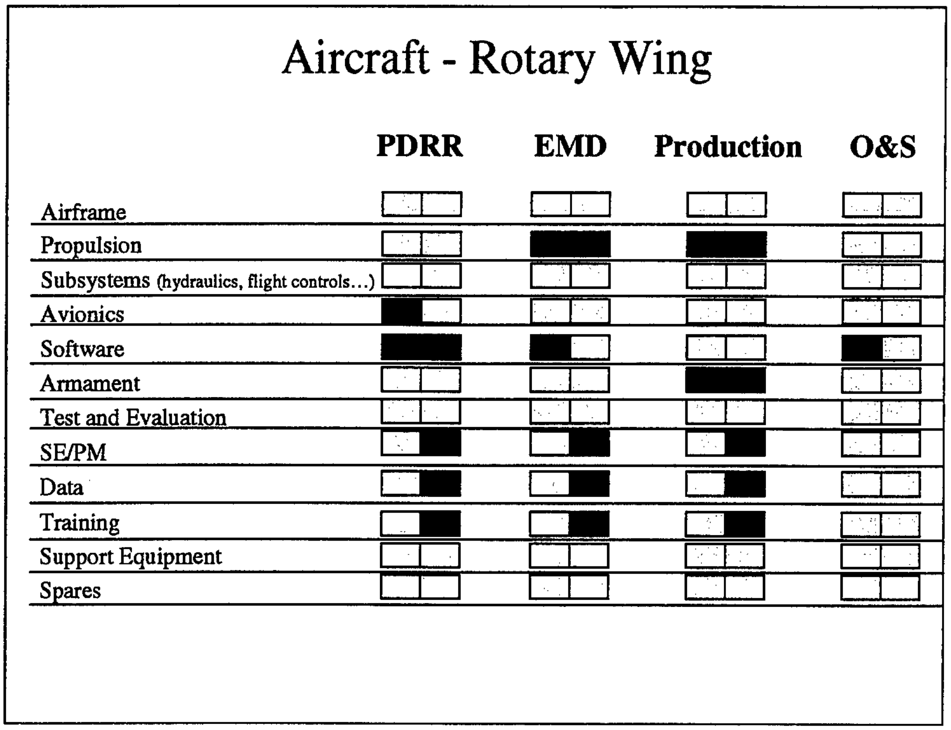
Avionics	
	MACDAR Fighter Aircraft Database, Tecolote, 1997
	A Data Base of Airborne Avionics, Tecolote, Jan 95
	Electronic Box/Electro-optical Equip Cost Analysis Brief, Tecolote, Sept 86
	Airborne & Ground Mobile Electronic Box Analysis, Tecolote, Sept 86
	Black Box Estimator - Electronics Cost Models, Tecolote, Nov 87
	Electronic Systems RDT&E Cost Model, MCR, May 88
	Cost Impacts of Electronic Boxes due to Basing Modes, Tecolote, Sept 87
	Radar Production Cost Model, MCR, May 88
	Kanter's Factors, Cost Factors and Estimating Relationships, Electronic Sys Division, Apr 90
	Electronic Subsystem Integration Estimator, TASC, Jul 85
	Military Tactical Aircraft Development Costs, IDA, 1988
	Aircraft Avionics & Missile System Installation Cost Study, MCR, 1988
	GFE, NAVAIR Database, 1997
	Price H, HL, M, General Electric, 1997
	SEER H
Software	
	Software Development Estimating Handbook - Phase One, NCCA, 1998
	Price S, Parametric Review of Info for Costing and Evaluation Software Sizing Model, GE, 1997
	SEER SEM, Systems Evaluation and Estimation Resources-S/W Est Model, Galorath, 1997
	Kanter's Factors, Cost Factors and Estimating Relationships, Electronic Sys Division, Apr 90
	Revic, Software Cost Estimating Model, AFCAA, Feb 91
	SASET, Software Architecture Sizing and Estimating Tool, Martin Marietta, Apr 93
Armament	
	MACDAR Fighter Aircraft Database, Tecolote, 1997
Test & Evaluation	
	MACDAR Fighter Aircraft Database, Tecolote, 1997
	Advanced Fighter Aircraft Cost Model, AFCAA, 1997
	Development Eng. and BTL Development Cost Models, Technomics, Aug 90
	Kanter's Factors, Cost Factors and Estimating Relationships, Electronic Sys Division, Apr 90
	Aircraft Airframe CERs, RAND, 1987 (Total Level)
	Assessing Acquisition Schedules for Tactical Aircraft, IDA 1989

SE/PM	
	AFCAA, Below the Line Cost Factors, 1998
	MACDAR Fighter Aircraft Database, Tecolote, 1997
	Advanced Fighter Aircraft Cost Model, AFCAA, 1997
	SE/PM Database, TASC, 1997
	Standard Cost Factors Handbook, NCCA, 1992
	Cost Factors for A/C and Missiles, Aeronautical Systems Division, May 87
	CER Develoment for R&D Data and SE/PM, Applied Research, Mar 90
	Development Eng. and BTL Development Cost Models, Technomics, Aug 90
	Kanter's Factors, Cost Factors and Estimating Relationships, Electronic Sys Division, Apr 90
	Aircraft Airframe CERs, RAND, 87 (Total Level)
Data	
	AFCAA, Below the Line Cost Factors, 1998
	MACDAR Fighter Aircraft Database, Tecolote, 1997
	Advanced Fighter Aircraft Cost Model, AFCAA, 1997
	Standard Cost Factors Handbook, NCCA, 1992
	HAPCA data, NAVAIR, 1991
	Cost Factors for A/C and Missiles, Aeronautical Systems Division, May 87
	Development Eng. And BTL Development Cost Models, Technomics, Aug 90
	CER Develoment for R&D Data and SE/PM, Applied Research, Mar 90
	Kanter's Factors Cost Factors and Estimating Relationships, Electronic Sys Division, Apr 90
	Aircraft Airframe CERs, RAND, 87 (Total Level)
Training	
	AFCAA, Below the Line Cost Factors, 1998
	MACDAR Fighter Aircraft Database, Tecolote, 1997
	Advanced Fighter Aircraft Cost Model, AFCAA, 1997
	Standard Cost Factors Handbook, NCCA, 1992
	HAPCA data, NAVAIR, 1991
	Cost Factors for A/C and Missiles, Aeronautical Systems Division, May 87
	Development Eng. and BTL Development Cost Models, Technomics, Aug 90
	Kanter's Factors, Cost Factors and Estimating Relationships, Electronic Sys Division, Apr 90

Support Equipment	
	AFCAA, Below the Line Cost Factors, 1998
	MACDAR Fighter Aircraft Database, Tecolote, 1997
	Advanced Fighter Aircraft Cost Model, AFCAA, 1997
	Standard Cost Factors Handbook, NCCA, 1992
	Cost Factors for A/C and Missiles, Aeronautical Systems Division, May 87
	Development Eng. And BTL Development Cost Models, Technomics, Aug 90
	CER Develoment for R&D Tooling , Applied Research, Mar 90
	Kanter's Factors, Cost Factors and Estimating Relationships, Electronic Sys Division, Apr 90
	VAMOSC
Spares	
	MACDAR Fighter Aircraft Database, Tecolote, 1997
	Kanter's Factors, Cost Factors and Estimating Relationships, Electronic Sys Division, Apr 90
	OP-20, Obligated Spend Profiles, NAVAIR, annual
O&S	
	AFI 65-503, USAF Cost Planning Factors
	VAMOSC
	Abides
	Tri-Service LCC Model, EER Systems, Unknown
	LCC Models Reference Guide,ASD, Apr 83
	Modeling the Cost of Ownership for Aircraft, RAND, Aug 81
	Estimating Recoverable Spares Investment, RAND, Aug 80
	DCA Circular 600-60-1, Cost & Planning Factors, TASC, Mar 83
	Naval Fixed Wing Aircraft O&S Cost Estimating Model, Delta Research, 1990
	Naval Aircraft Modification Database, MCR, 1996
	Line Shut-Down Study, MCR, 1996
	C3 Platform Integration Cost Model, MCR, 1997
	Estimating Annual O&S Cost, Watson Noah, Jan 75
	Avionics Parametric Cost Model, ASD, Feb 73
	PPR Data / SDLMs (Depot Level Maintenance), NADOC, annual
	OP-20, Obligated Spend Profiles, NAVAIR, annual

IV. ROTARY-WING AIRCRAFT

Theresa O'Brien, Air Force Cost Analysis Agency



Survey respondents for rotary-wing aircraft primarily were from CEAC, AMCOM, and at a top level from NAVAIR.

The Army has created a database of CCDRs for all rotary-wing aircraft. This database provides valuable historical data for analogies or factors.

Like the fixed-wing aircraft, composites are a challenge for estimating the Airframe portion.

The Propulsion area has a current, detailed database available to analyst. Again, the challenge is capturing the cost to enhance existing systems.

The areas of Subsystems and Avionics are not coded as red as they are for fixed-wing aircraft, primarily due to the models used and the respondent's comfort level (see the following list of models and studies). The trouble with the existing models is that they require detailed inputs that the analyst is typically lacking at the time of the estimate.

SE/PM, Data, Training, and Support Equipment are coded similarly based on the databases containing the historical data and not capturing acquisition streamlining initiatives the contractors are implementing.

Finally, a comment on Support Equipment. One remark on the survey noted the vast amount of equipment required to support rotary-wing aircraft and the challenges it presents to the estimator.

I would now like to turn the presentation over to Rick Collins from NCCA.

Airframe

ACDB Aircraft-Rotary Wing, SAIC, 1997
Rotary Wing Cost Factor Study, SAIC, 1996
Composites/Exotic Materials Database, Tecolote, 1997
Advanced Airframe Structural Materials, RAND Study, 1991
ACDB Aircraft-Rotary Wing, SAIC, 1997
Cost Considerations for LO Technology for the Comanche Helo, SAIC, 1994
Dev. of Cost Est. Methodologies for Composite Aircraft Structures and Components, LSA, 1988
CERs by WBS for Selected Helicopter Systems, CALIBER Systems, 1991

Propulsion

ACDB Aircraft-Rotary Wing, SAIC, 1997
Rotary Wing Cost Factor Study, SAIC, 1996
Aircraft Gas Turbine engine Acquisition Costs, Ketron, 1997
CERs by WBS for Selected Helicopter Systems, CALIBER Systems, 1991

SubSystems

ACDB Aircraft-Rotary Wing, SAIC, 1997
Rotary Wing Cost Factor Study, SAIC, 1996

Avionics

ACDB Aircraft-Rotary Wing, SAIC, 1997
Rotary Wing Cost Factor Study, SAIC, 1996
Parametric Approach to Est. Cost of Dev. Eng. ARI/87 TM-387, Applied Research Inc., 1987
Electronics Cost Model (TR-9505-01) Technomics, 1996
Parametric Avionics/Electronics Procurement & A/C Retrofit Cost Study/ Vol II, General Dynamics, 1984
CERs by WBS for Selected Helicopter Systems, CALIBER Systems, 1991
Organizational Options for Common Elec Mgmt., IDA, 1992
Tactical Strategic IR Sensor, Technomics, 1992

Software

Price S, Parametric Review of Info for Costing and Evaluation Software Sizing Model, GE, 1997
SEER SEM, Systems Evaluation and Estimation Resources-S/W Est Model, Galorath, 1997
Revic, Software Cost Estimating Model, AFCAA, Feb 91
SASET, Software Architecture Sizing and Estimating Tool, Martin Marietta, Apr 93
Development Support Cost Model (TR9505-04), Technomics, 1996

Armament

ACDB Aircraft-Rotary Wing, SAIC, 1997
Rotary Wing Cost Factor Study, SAIC, 1996

Test & Evaluation

ACDB Aircraft-Rotary Wing, SAIC, 1997
Rotary Wing Cost Factor Study, SAIC, 1996

SE/PM

ACDB Aircraft-Rotary Wing, SAIC, 1997
Rotary Wing Cost Factor Study, SAIC, 1996

Data

ACDB Aircraft-Rotary Wing, SAIC, 1997
Rotary Wing Cost Factor Study, SAIC, 1996
HAPCA data, NAVAIR, 1991

Training

HAPCA data, NAVAIR, 1991

Support Equipment

VAMOSC - AMSR
OSMIS
Force Cost Model, CEAC, 1997

Spares

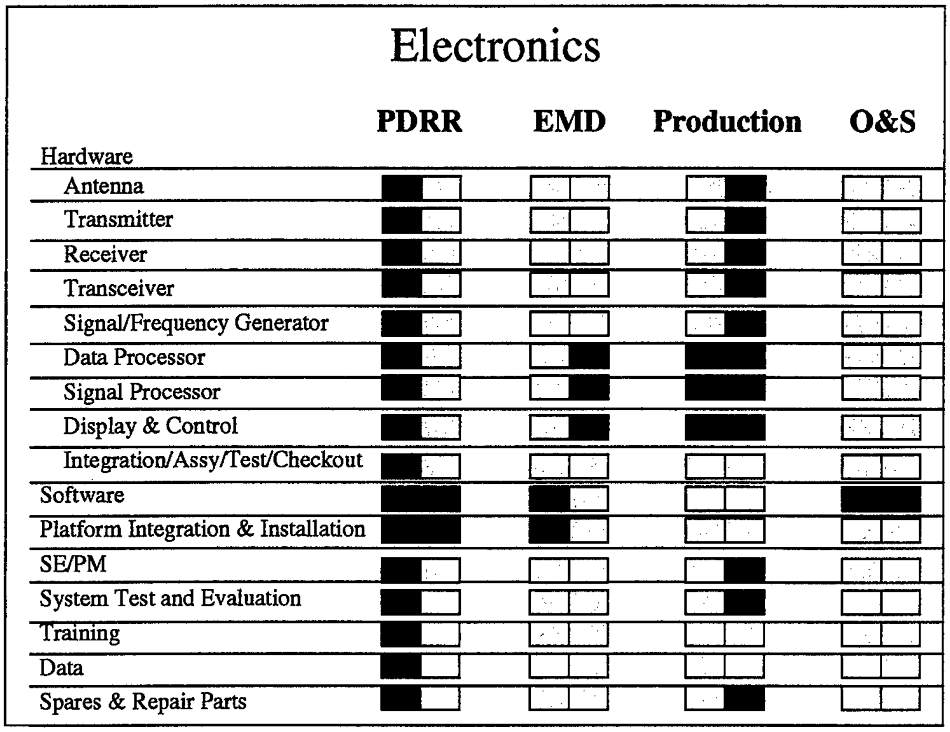
OP-20, Obligated Spend Profiles, NAVAIR, annual
CASA Cost Analysis Strategy Assement, DSMC, 1997

O&S

VAMOSC / OSMIS
PPR Data / SDLMs (Depot Level Maintenance), NADOC, annual
OP-20, Obligated Spend Profiles, NAVAIR, annual
Tri-Service LCC Model, EER Systems, Unknown
Modeling the Cost of Ownership for Aircraft, RAND, Aug 81
Estimating Annual O&S Cost, Watson Noah, Jan 75
Naval Rotary Wing Aircraft O&S Cost Estimating Model, Delta Research, 1990
Force Cost Model, CEAC, 1997

V. ELECTRONICS

Richard Collins, Naval Center for Cost Analysis



This slide depicts the assessment of electronics cost estimating capability. The assessment is based on inputs from representatives of nine DoD and two private sector organizations, including the following:

- AFCAA
- ESC/FMC
- CECOM
- NAVAIR
- NAVSEA
- NSWC/Dahlgren Division
- NCCA
- OSD CAIG
- BMDO
- Technomics, Inc.
- Tecolote Research, Inc.

In general, the assessment tends to mirror the expectations discussed earlier. With a few exceptions, PDRR is rated red-yellow, EMD is rated yellow, production is rated yellow-green, and O&S is rated yellow. I will focus my comments on the significant (with respect to percent of total cost) areas where the assessment differs from the expectations, but I want to make some general comments before doing so. First, several of the contributors to this assessment warned that the pace of electronics technology evolution translates to cost models having short shelf lives (i.e., two to five years depending on the component). Second, and directly related to the first comment, it is imperative that electronics cost estimating methodology incorporate, to the extent possible, the impact of technology trends.

Next, I will address the significant areas where the assessment was worse than expected.

- <u>Software</u>: A number of factors contributed to the nearly 100-percent red rating. First, with respect to data, the quantity and quality of development and maintenance data are viewed as problematic. Second, with respect to methodology, the heavy reliance of existing models (public domain and commercial) on subjective inputs is viewed as problematic. Third, with respect to technical definition, the uncertainty in sizing estimates is viewed as problematic.
- <u>Platform Integration and Installation</u>: The rationale for the assessment is quite simple—lack of understanding of the explanatory variables, no compilation of data and no methodology. With respect to the data void, cost reports typically do not provide the visibility required to isolate these costs.

Finally, I will address the significant areas where the assessment was better than expected.

- <u>Processor and Display and Control Hardware</u>: The relatively favorable assessment is directly related to the increasing application of commercial off-the-shelf (COTS) equipment for these functions. Specifically, with respect to recurring hardware costs, availability of COTS price information and knowledge of COTS price trends for these types of equipment is the basis for the positive perspective.

The next slides are a representative (but not exhaustive) compilations of the electronics estimating databases and methodology that the eleven contributing organizations use.

Electronics Estimating Databases & Methodology

Hardware

Acquis
- The Black Box Estimators Electronics Cost Models, Tecolote, Nov 87
- Communications and Electronics Cost Model, Technomics, Oct 96
- Electronics Cost Model, Technomics, Jan 96
- CERs for Shipboard RF Sensors, Technomics, Jan 92
- Radar Engineering and Cost Tool (REACT), Tecolote, Dec 93
- COTS Electronics Cost and Technical Database, LSA Inc., May 96
- Digital Signal and Data Processor Model, Tecolote, Sep 91
- Ground Based Radar Signal and Data Processor CERs, Tecolote, Dec 93
- Radar Receiver Estimating Model, Tecolote, Feb 96
- T/R Module Cost Model, Tecolote, 1996 (update due Mar 98)
- Microwave and Digital Cost Analysis Model (MADCAM), Tecolote, Mar 96 (update due Apr 98)
- Circuit Card Assembly Database, NSWC/Crane Division, Oct 96
- Estimating Nonrecurring Design Cost and Development Time in Avionics Programs, MCR, Dec 97
- Development Engineering and Below-the-Line Development Cost Models, Technomics, Aug 90
- Analyses of the Relationship Between Development and Production Unit Hardware Costs, NCCA, Jan 94
- An Analysis of Electronics Systems Learning and Rate Effects, NCCA, May 93
- Procedures for Estimating Life Cycle Costs of Electronic Combat Equipment, Rand, Feb 88
- PRICE H

O&S
- Visibility and Management of Operating and Support Costs (VAMOSC) Database
- Operating and Support Cost Analysis Model (OSCAM)-Ship Systems, NCCA & HVR Consulting, Jan 98
- COTS Electronics Technology Assessment/Refresh Cost Model, NSWC/Crane Division, Sep 97
- Cost of Manpower Estimating Tool (COMET), NCCA & SAG, Dec 97
- Army Military-Civilian Cost System
- C3 Hardware Maintenance Statistical Analysis, MCR, 97
- PRICE HL

Electronics Estimating Databases & Methodology (2)

Software

Acquis
- Software Development Cost Estimating Handbook, NCCA, Jan 98
- SMC Software Database, MCR Federal, annual updates
- CERs for Software Development, Aerospace Corp., May 96
- PRICE S, SEER-SEM & Riefer models
- CERs for Space-Based Systems, Defense Communications Agency-DC, Apr 91
- ESC/FMC Software Factors and Estimating Relationships, Dec 95

Platform Integration & Installation
- C3 Platform Integration Model, MCR, 97
- Electronic Subsystem Integration Estimator, TASC, Jul 85
- System Engineering/Integration CER Update, Tecolote, Aug 92
- PRICE H

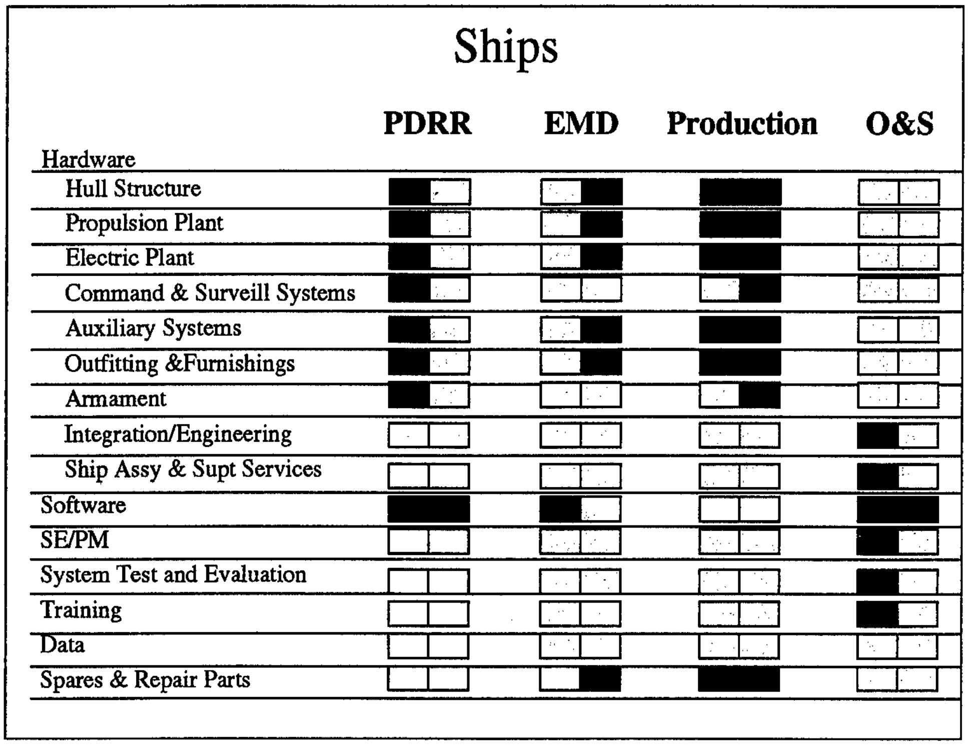
SE/PM, ST&E and Other Support Elements

Acquis
- ESC/FMC Acquisition Support CERs and Factors, Tecolote, Sep 93
- System Engineering/Integration CER Update, Tecolote, Aug 92
- Development Engineering and Below-the-Line Development Cost Models, Technomics, Aug 90
- SESAME Model
- Electronic Equipment: Cost of Spares Research, Cygnus, 95

O&S
- Visibility and Management of Operating and Support Costs (VAMOSC) Database
- Operating and Support Cost Analysis Model (OSCAM)-Ship Systems, NCCA & HVR Consulting, Jan 98
- Cost of Manpower Estimating Tool (COMET), NCCA & SAG, Dec 97
- Army Military-Civilian Cost System

VI. SHIPS

Richard Collins, Naval Center for Cost Analysis



This slide depicts the assessment of ships cost estimating capability. The assessment is based on inputs from representatives of four DoD organizations, including the following:

- NAVSEA
- NSWC/Carderock Division
- NCCA
- OSD CAIG

The assessment for PDRR and EMD tends to mirror the expectations discussed earlier. With a few exceptions, PDRR is rated red-yellow and EMD is rated yellow. The assessment for production tends to differ from the expected yellow-green; it is principally a mix of either yellow or green. Finally, the assessment for O&S differs from the expected yellow in several areas and is red-yellow. I will focus my comments on the significant (with respect to percent of total cost) areas where the assessment differs from the expectations.

Next, I will address the significant areas where the assessment was worse than expected.

- Software: A number of factors contributed to the nearly 100-percent red rating. First, with respect to data, the quantity and quality of development and maintenance data are viewed as problematic. Second, with respect to methodology, the heavy reliance of existing models (public domain and commercial) on subjective inputs is viewed as problematic. Third, with respect to technical definition, the uncertainty in sizing estimates is viewed as problematic.
- Integration/Engineering Hardware, Ship Assembly and Support Services Hardware, SE/PM, System Test and Evaluation, Training, and Data: The rationale for the assessment is quite simple—lack of understanding of the explanatory variables resulting in little to no meaningful methodology.

Finally, I will address the significant areas where the assessment was better than expected.

- Hardware and Spares and Repair Parts: Hull, propulsion, electric, auxiliary, and outfittings and furnishings are viewed as less complex subsystems that are better understood than the more complex electronics-oriented command and surveillance and armament subsystems. This same rationale applies to the spares and repair parts associated with these subsystems.

Ships Estimating Databases & Methodology

Hardware

Acquis	Historical Ship Cost (HCOST) Database, NAVSEA
	Unit Price Analysis (UPA) Model, NAVSEA
	Product Oriented Design & Construction (PODAC) Cost Model, NSWC/Carderock Division et. al., Feb 97
	ASSET/ACE Interface(AACEI) Cost Model, Tecolote, Sep 96
	Nuclear Attack Submarine Performance-Based Cost Model, NSWC/Carderock Division, Jun 96
	U.S. Naval Vessels Detail Design Cost Estimating Models, Gibbs & Cox, Jun 91 & Jul 92
	U.S. Naval Surface Ships Construction Cost Model, Gibbs & Cox, Jun 94
	U.S. Naval Ship Upgrade Construction Cost Model, Gibbs & Cox, Aug 95
	Ship Construction Cost & Technical Database, NCCA, Feb 93
	Ship Construction Manhour & Material Cost Learning Curves, NCCA, Jan 94
O&S	Visibility and Management of Operating and Support Costs (VAMOSC) Database
	Operating and Support Cost Analysis Model (OSCAM)-Ships, NCCA & HVR Consulting, Jan 98
	Operating and Support Cost Analysis Model (OSCAM)-Ship Systems, NCCA & HVR Consulting, Jan 98
	Cost of Manpower Estimating Tool (COMET), NCCA & SAG, Dec 97

Software

Acquis	Software Development Cost Estimating Handbook, NCCA, Jan 98
	SMC Software Database, MCR Federal, annual updates
	CERs for Software Development, Aerospace Corp., May 96
	PRICE S, SEER-SEM & Riefer models

SE/PM, ST&E and Other Support Elements

Acquis	Historical Ship Cost (HCOST) Database, NAVSEA
	Unit Price Analysis (UPA) Model, NAVSEA
O&S	Visibility and Management of Operating and Support Costs (VAMOSC) Database
	Operating and Support Cost Analysis Model (OSCAM)-Ships, NCCA & HVR Consulting, Jan 98
	Operating and Support Cost Analysis Model (OSCAM)-Ship Systems, NCCA & HVR Consulting, Jan 98
	Cost of Manpower Estimating Tool (COMET), NCCA & SAG, Dec 97

This slide is a representative (but not exhaustive) compilation of the ships estimating databases and methodology that the four contributing organizations use.

VII. MISSILES

Richard Bishop, US Army Cost and Economic Analysis Center

MISSILES

	PDRR	EMD	Production	O&S
Air Vehicle				
. Propulsion	■□	■□	■□	■□
. Payload	□□	□■	□■	□□
. Airframe	■□	■□	□□	□□
. Guidance and Control	□□	□□	□■	□□
. Airborne Test Equipment	□□	□□	□■	□□
. Integration/Assy/Test/Checkout	□□	□□	□□	□□
Command and Launch				
. Surveillance, ID & Track Sensor	□□	□□	□■	□□
. Launch & Guidance Control	□□	□□	□■	□□
.Communications	□□	□□	□■	□□
. Launcher Equipment	■□	■□	□□	□□
System Eng/Program Mgmt	□■	□■	□■	□□
System Test & Evaluation	□■	□■	□■	□□
Training	□■	□■	□■	□□
Peculiar/ Common Support Equip	□□	□■	□■	□□
Initial Spares & Repair Parts	□■	□■	□■	□□

Four organizations sent us data: (1) Army Aviation and Missile Command; (2) Army Space and Missile Defense Command; (3) NAVAIR; and (4) AFCAA.

Overall, the missiles area is in relatively good condition (yellow-green). This can be attributed to the fact that CCDR data have been required and collected by the Army, Navy, and Air Force. In addition, many missile studies and models have been developed.

Production has a great deal of green.

Launcher Equipment is red in PDRR and EMD.

Surprises are the red in Propulsion and Airframe and no red in Guidance and Control.

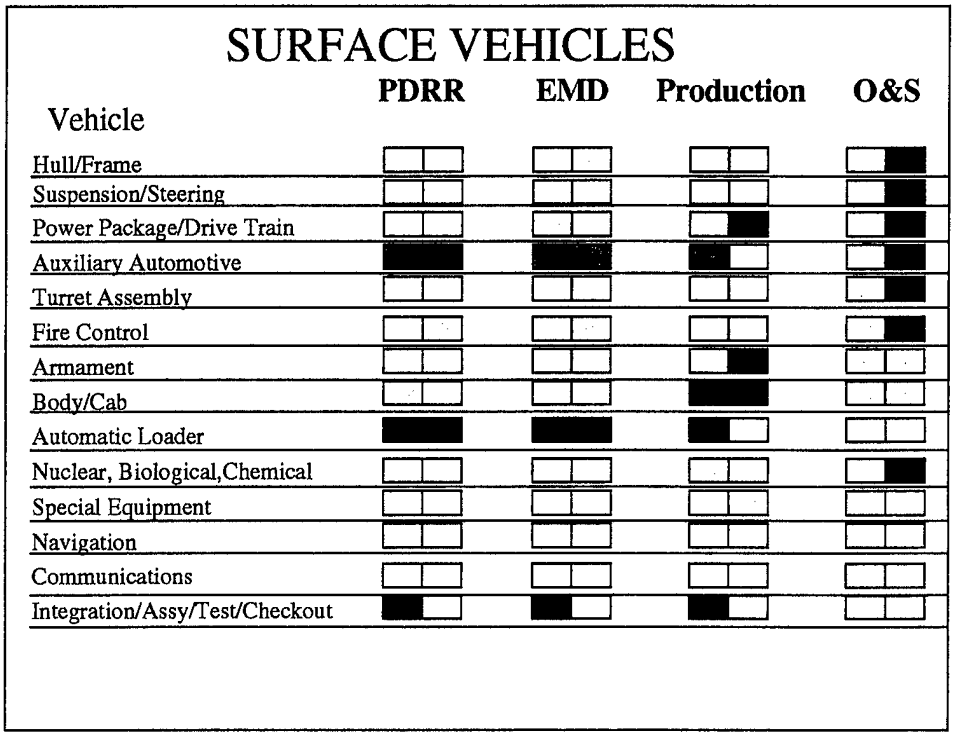
Propulsion methodology is aging and needs to be updated.

Airframe is red, probably because of Composite Materials.

Guidance and Control Seekers was a big unknown area a few years ago, but we have studied them and now have actuals for imaging infra-red. Also, millimeter wave seekers are not the big mystery that they once were.

VIII. SURFACE VEHICLE SYSTEMS

Richard Bishop, US Army Cost And Economic Analysis Center



Data are from the Army Tank and Automotive Command and CEAC.

The overall comment from TACOM was that they have data and methods for all areas except for materials that push the state of the art.

Auxiliary Automotive is red in all phases except O&S; we have no data for these sub-systems.

Automatic Loader: we have no data for the few previous Army systems.

For Integration and Assembly, we lack the appropriate level of detail and have no confidence in parametric methods.

The OSMIS database has historical data for most of the other items. The CEAC OSMIS team members believe they can develop a better estimate at PDRR abd EMD than most can at the production milestone.

SURFACE VEHICLES (p.2)

	PDRR	EMD	Production	O&S
SE/PM	■	■	■	■
System Test and Evaluation	□	□	□	□
Training	■	□	□	□
Peculiar Support Equipment	□	□	□	■
Common Support Equipment	□	□	□	■
Initial Spares & Repair Parts	■	■	■	□

Training is red at PDRR because training devices are ill defined at this point in time.

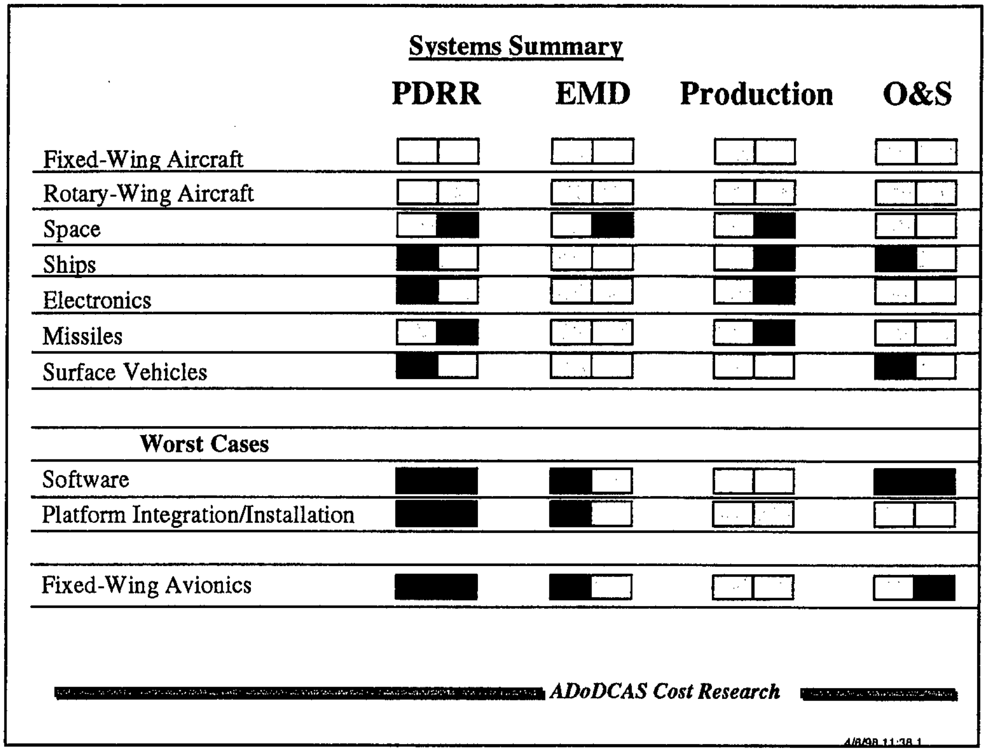
Initial Spares and Repair Parts: red until O&S.

There is a lack of data at the level required. The SESAME model requires extensive data input and the proposed simplified SESAME Model still needs seventeen detailed, accurate inputs for a parametric estimate in which there is little confidence until actuals are available. The OSMIS Team recommends using analogous OSMIS data for projection.

Peculiar and Common Support Equipment categories are red for O&S due to a lack of sufficient detail in the historical data.

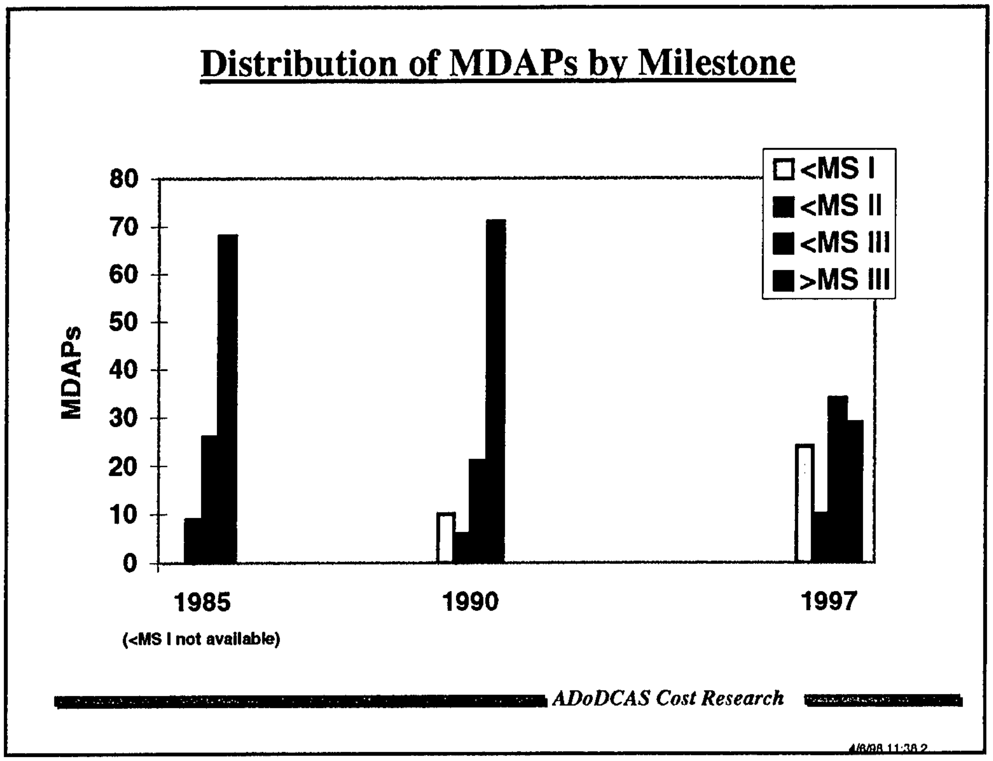
IX. OSD PERSPECTIVE

Vance Gordon, Office of the Deputy Director (Resource Analysis), Program Analysis and Evaluation



This slide summarizes my colleagues' presentations. As Steve Balut predicted, the uncertainty of our estimates is greatest at Milestones I and II, and decreases as we approach production. This is not new news, but it is a more systematic view than we have previously been able to present.

It is, moreover, important to bear in mind that this picture captures our uncertainty at each milestone. If a similar chart were prepared for our uncertainty *at Milestone I* of the costs of each phase, it would be far more red than this one. As the next slide shows, this should give us strong reason for concern.

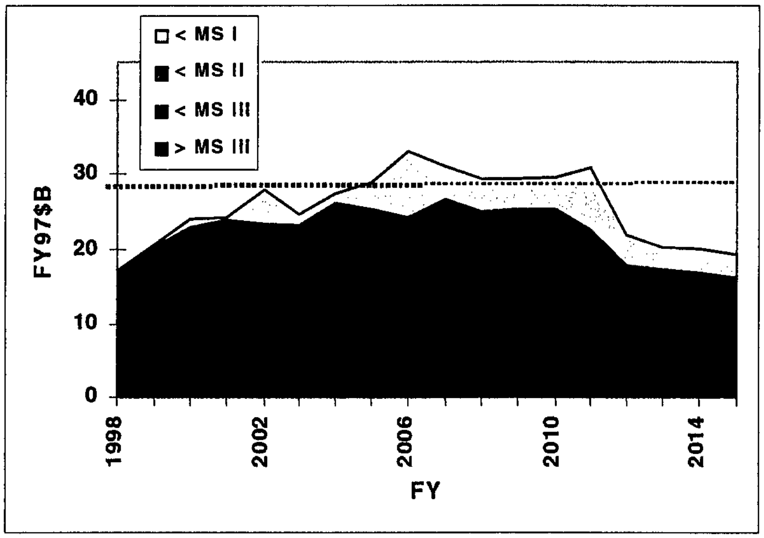


The challenges we can expect to face in the next decade are in precisely that area in which our current tools are weakest: the estimation of life-cycle costs for programs in the early stages of development.

This slide depicts the distribution of MDAPs at three times: in the middle of the Reagan defense build-up, at the end of the Cold War, and today. In contrast to the earlier years, we have today a preponderance of programs in the early stages of development. In fact, the distribution we see today has only one historical precedent, in the set of programs on hand in the late 1970s, which came to adulthood in the distribution we see in 1985.

As shown in the next slide, today's distribution of programs poses a future funding problem as well as a cost-estimating challenge.

Projected Procurement Costs for Current MDAPS



ADoDCAS Cost Research

This slide shows, in FY 1997 dollars, the currently projected procurement costs for the MDAPs shown in the last slide. The total annual requirement during FY 2006-2012 is about $13 billion more than we will spend on MDAP procurement this year, and leaves no room for error within the targeted increase in our procurement funding, which is shown by the dotted line.

It is therefore likely that hard decisions will be required to fit the future defense acquisition program within the available funds. The wisdom of those decisions will depend absolutely on the realism of our cost estimates, which in turn depends on the quality of the tools we are able to bring to bear.

It is for that reason that we have embarked on the current effort to define and improve the status of DoD cost research.

X. CLOSING

Stephen J. Balut, Institute for Defense Analyses

WHAT'S NEXT

- Document this assessment
- Update Cost Research Roadmap
- Review ongoing cost research
  - Catalog projects
- Prepare FY 1999 Cost Research Program
  - Decentralized
  - Informed

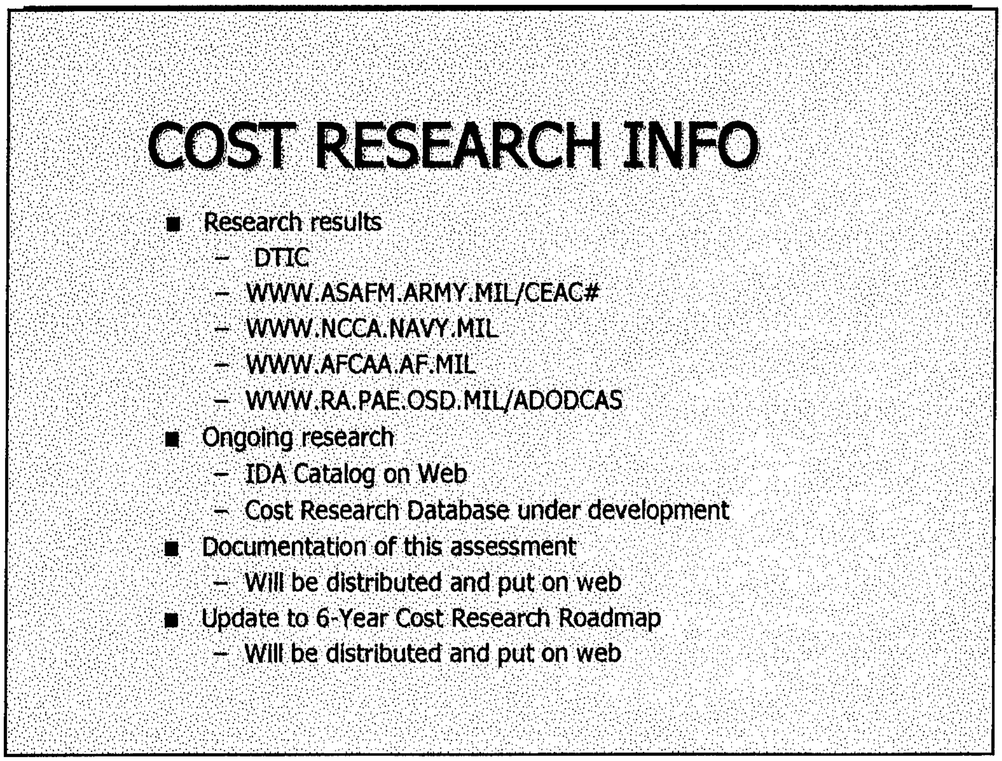
We're going to open the floor to questions in a moment. First, I want to let you know what comes next for cost research in the DoD, and where you can get more information about cost research.

Our panel will document the assessment you've just seen and place it on the internet. Documentation will include the slides you saw here, and also backup materials used to develop the scores.

Over the next few months, we will be updating the DoD Cost Research Plan in light of what you've seen here today. The updated Plan is intended to guide subsequent research investments to areas of greatest need.

Next, we will review ongoing research activities at the IDA/CAIG Cost Research Symposium to be held in May. A draft catalog of projects in progress or planned will be given to participants at that time. This catalog will be finalized in August and will be placed on the web.

Then we get to the real purpose of this cycle of annual planning. During the summer, sponsors will select topics for study during FY 1999. They will make these selections in a decentralized way, but their decisions will be informed—informed by the assessments at DoDCAS, the updated roadmap, and knowledge of the current status of ongoing cost research as contained in the catalog.



This slide shows where you can go to get more information on cost research. Many completed studies are sent to DTIC. Others are not and are sometimes made available by the sponsoring office directly. In some cases, results are placed on web sites. This slide lists some of these sites.

The only place to get a broad view of ongoing research is in the catalog produced in conjunction with the Cost Research Symposium. The catalog is placed on the web. For example, the 1997 catalog is now on the OSD ADODCAS site in Adobe Acrobat format.

Also, the CAIG is developing a cost research database and will make it available to users when completed.

Documentation of the assessment you heard today will be placed on the web—on the ADODCAS site. The update to the DoD Six-Year Cost Research Plan will also be put on that web site.

APPENDIX

OFFICES CONTRIBUTING TO THE ASSESSMENTS

Space Systems

Air Force Cost Analysis Agency (AFCAA)

Air Force Space and Missile Systems Center (AFSMC)

Fixed Wing Aircraft

Air Force Cost Analysis Agency (AFCAA)

Naval Air Systems Command (NAVAIR)

Naval Center for Cost Analysis (NCCA)

Air Force Materiel Command/Aeronautical Systems Center (HSC/EMP)

Rotary Wing Aircraft

Army Cost & Economic Analysis Center (CEAC)

Army Aviation and Missile Command (AAMC)

Naval Air Systems Command (NAVAIR)

Electronics

Air Force Cost Analysis Agency (AFCAA)

Air Force Electronics Systems Center (ESC/FMC)

Army Communications & Electronics Command (CECOM)

Naval Air Systems Command (NAVAIR)

Naval Sea Systems Command (NAVSEA)

Naval Surface Warfare Center Dahlgren Division (NSWCDD)

Naval Center for Cost Analysis (NCCA)

OSD Cost Analysis Improvement Group (CAIG)

Ballistic Missile Defense Organization (BMDO)

Technomics, Inc.

Tecolote Research, Inc.

Ships

Naval Sea Systems Command (NAVSEA)

Naval Surface Warfare Center Carderock Division (NSWCCD)

Naval Center for Cost Analysis (NCCA)

OSD Cost Analysis Improvement Group (CAIG)

Missiles

Air Force Cost Analysis Agency (AFCAA)

Army Aviation & Missile Command

Army Cost & Economic Analysis Center (CEAC)

Army Space and Missile Defense Command

Naval Air Systems Command (NAVAIR)

Navy Center for Cost Analysis (NCCA)

Surface Vehicle Systems

Army Tank – Armament and Automotive Command (ATAAC)

Army Cost & Economic Analysis Center (CEAC)

OSD Perspective

Office Secretary of Defense (OSD (PA&E))

ABBREVIATIONS

AFCAA	Air Force Cost Analysis Agency
ASC	Aeronautical Systems Center
BMDO	Ballistic Missile Defense Organization
C/SSR	Cost/Schedule Status Report
C^3	command, control, and communications
CAIG	Cost Analysis Improvement Group
CAIV	cost as an independent variable
CCDR	Contractor Cost Data Reporting
CEAC	Cost and Economic Analysis Center
CECOM	Army Communications and Electronics Command
CER	cost-estimating relationship
COTS	commercial off-the-shelf
CPR	Cost Performance Report
CR	cost research
DAB	Defense Acquisition Board
DoD	Department of Defense
DoDCAS	DoD Cost Analysis Symposium
DTIC	Defense Technical Information Center
EELV	Evolved Expendable Launch Vehicle
EMD	Engineering and Manufacturing Development
ESC/FMC	Air Force Electronics Systems Center
FFRDC	Federally Funded Research and Development Center
IDA	Institute for Defense Analyses
JSF	Joint Strike Fighter
LRIP	low-rate initial production
MDAP	Major Defense Acquisition Program
MS	Milestone
NAFCOM	NASA/Air Force Cost Model
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NCCA	Naval Center for Cost Analysis
NSWC	Naval Surface Weapons Center

O&S	operating and support
OSD	Office of the Secretary of Defense
PDRR	Program Definition and Risk Reduction
SE/PM	system engineering/project management
TACOM	Tank and Automotive Command
USA	United States Army
USCM	Unmanned Spacecraft Cost Model
VAMOSC	Visibility and Management of Operating and Support Cost
WBS	work breakdown structure

UNCLASSIFIED

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	April 1998	Final Report, Dec 1997–Apr 1998

4. TITLE AND SUBTITLE
"Status of DoD's Capability to Estimate the Costs of Weapon Systems"

5. FUNDING NUMBERS
DASW01 94 C 0054/
DASW01 97 C 0056
T-Q7-1138

6. AUTHOR(S)
Stephen J. Balut, Vance Gordon, Theresa O'Brien, Richard Bishop, and Richard Collins

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Institute for Defense Analyses
1801 N. Beauregard Street
Alexandria, VA 22311-1772

8. PERFORMING ORGANIZATION REPORT NUMBER
IDA Document D-2149

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Dr. Vance Gordon
OD(PA&E), Room 2E314
Washington, DC 20301-1800

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12A. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

12B. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 words)***

Suppose you are the cost analyst responsible for estimating the cost of a weapon system (e.g., tactical aircraft) in preparation for a major milestone review (e.g., Milestone II, Engineering and Manufacturing Development). Do you have the data you need? Do you have the right methods (e.g., cost-estimating relationships) and tools (e.g., automated models)? At the 1998 DoD Cost Analysis Symposium, representatives from each of the Military Departments answered these questions as best they could for all major commodity types. The Air Force representative addressed aircraft and space systems; the Navy representative discussed ships and electronics; and the Army representative addressed missile systems, land vehicles, and ordnance. A representative from the OSD Cost Analysis Improvement Group (CAIG) added the CAIG perspective and provided highlights of the upcoming Defense Acquisition Board schedule where these estimates will be needed. The findings of this panel of representatives will be used to revise the DoD Six-Year Cost Research Plan that will guide future investments in DoD cost research.

14. SUBJECT TERMS
Cost Estimates; Military Aircraft; Naval Vessels; Spacecraft; Missiles; Electronics; Ordnance; Vehicles

15. NUMBER OF PAGES
99

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

UNCLASSIFIED